This document contains the Draft EPA Report “Hull Coating Leachate Feasibility Impact Analysis Report” published in August 2003. The reference number is: EPA-842-D-06-004

DRAFT
Feasibility Impact Analysis Report
Hull Coating Leachate

August 2003

DRAFT

FEASIBILITY IMPACT ANALYSIS REPORT

Hull Coating Leachate

Prepared by:

Naval Sea Systems Command
U.S. Department of the Navy

Office of Water
U.S. Environmental Protection Agency

August 2003

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACEIT	Automated Cost Estimating Integrated Tool
ChAR	Characterization Analysis Report
CPI	Consumer Price Index
CVN	Nuclear Powered Aircraft Carrier
DOD	Department of Defense
EEAR	Environmental Effects Analysis Report
EPA	Environmental Protection Agency
FIAR	Feasibility Impact Analysis Report
MCM	Mine Countermeasures Ship
MHC	Coastal Mine Hunter Ship
MLB	Motor Lifeboat (USCG)
MPC	Maintenance Procedure Card
MPCD	Marine Pollution Control Device
MSC	Military Sealift Command
MSDS	Material Safety Data Sheet
OMB	Office of Management and Budget
PDS	Product Data Sheet
PPE	Personal Protective Equipment
QA	Quality Assurance
SSN	Attack Submarine, Nuclear-Powered
TBT	Tributyltin
TOC	Total Ownership Cost
UNDS	Uniform National Discharge Standards
USCG	United States Coast Guard

1.0 INTRODUCTION

The *Feasibility Impact Analysis Report* (FIAR) examines three of the seven considerations specified in the Uniform National Discharge Standards (UNDS) legislation for establishing performance standards for Marine Pollution Control Devices (MPCDs):

- Practicability of using the MPCD;
- Operational impact of installing or using the MPCD; and
- Costs of the installation and use of the MPCD.

Feasibility analyses were performed for each MPCD option group that passed the MPCD screening process. The specific criteria considered in the feasibility analyses are detailed in the *Feasibility Impact Analysis Guidance Document* (EPA and DOD, 2000, hereafter referred to as *Feasibility Guidance Document*).

1.1 Feasibility Factors

The *Feasibility Guidance Document* (EPA and DOD, 2000) describes the factors that are considered in each analysis. As discussed below, all of the factors listed in the *Feasibility Guidance Document* are not applicable to the hull coating leachate discharge.

1.1.1 Practicability and Operational Analysis Factors

The feasibility factors and their applicability to the hull coating leachate discharge are described below. The drydocking interval and pierside maintenance factor is unique to the hull coating leachate discharge.

Factors that do not require analysis:

Space and Volume: Space and volume requirements do not vary by MPCD option group for the hull coating leachate discharge.

Weight and Stability: The weight of the applied antifouling coating system is uniformly distributed over the wetted hull area and will not have a significant effect on the vessel's weight or stability.

Safety: All MPCD options require similar safety measures (i.e., personal protective equipment) that are standard to most painting operations. None of the MPCD options have safety concerns, provided these standard measures are properly managed.

Suitability for the Marine Environment: Suitability for the marine environment was considered in the MPCD identification and screening process. All MPCDs screened were considered suitable for the Marine Environment.

Personnel Impact: MPCD options have no direct impact on shipboard personnel.

Vessel Stage of Development: All MPCD options are applicable to existing and future vessels.

Interface Requirements: There are no interface requirements for hull coating leachate MPCD options.

Control System Requirements: There are no control system requirements for hull coating leachate MPCD options.

Equipment/Material: Any equipment and material needed to support the MPCD options are associated with underwater hull cleaning. The *Underwater Ship Husbandry Feasibility Impact and Analysis Report* includes a discussion of such equipment and materials.

Factors that require analysis:

Mission Capabilities: The effect of the MPCD option on vessel speed, range, and mission critical systems is discussed for each MPCD option and vessel group.

Drydocking Interval and Pierside Maintenance: Hull cleaning and drydocking interval may be affected by MPCD selection. The impact of each MPCD on drydocking interval and underwater hull cleaning is discussed as a single factor. The frequency and number of required underwater hull cleanings increase as the drydocking interval is increased. The maximum drydocking interval practicable for the MPCD and vessel group is assumed for the analyses. For small boats and craft, the terms “launching” and “hauling” more accurately describe the procedures for removing small boats or craft from the water for maintenance and will be used in this report when appropriate, but the term “drydocking” is retained for consistent section titles throughout the Hull Coating Leachate FIAR

Specific equipment and material to support hull cleaning activities are discussed in detail in the *Underwater Ship Husbandry Feasibility Impact and Analysis Report* and are not applicable to the Hull Coating Leachate discharge. Only the impact of hull cleaning frequency is included in this report. The frequency of hull cleaning is a function of the type of paint, age of the paint and the operational environment. For example, the vinyl antifouling paint, MIL-P-15931 Formula 121, is a coating that is capable of undergoing many (i.e., 14 or more) hull cleanings between paint applications. Ablative antifouling paints, as per MIL-PRF-24647, are not designed for such numerous cleanings based on the current guidance for authorization of hull cleanings (Navy, 1999). Foul-release coatings, as per MIL-PRF-24647, are even more delicate than copper ablative coatings and require less aggressive cleaning actions than either ablative copper or vinyl coatings (McCue, 2003a).

1.1.2 Cost Analysis Factors

The cost analyses are for comparison only and are not intended for preparation of budgets or determination of actual costs. Incremental costs are additional expenses that the Armed Forces would incur as a result of the implementation of UNDS regulatory requirements and could include initial and recurring costs.

Costs were estimated using actual information from vendors and shipyard historical information. The Automated Cost Estimating Integrated Tool (ACEIT) software was used to total costs over a 12-year period, adjust the costs to 1999 dollars, and annualize costs. The 12-year period corresponds to the drydock interval for the largest vessel class. Drydocking related maintenance (i.e., re-preservation) is the major cost factor associated with the discharge. Using the same interval for annualizing costs provides an accurate cost analysis. The ACEIT software is widely used within the U.S. Department of Defense (DOD) cost analysis community (ACEIT, 2001). All cost data presented were converted to 1999 dollars using the annual Consumer Price Index (CPI) data. The CPI is a general inflation rate published by the Bureau of Labor Statistics.

Initial Costs: One-time, initial costs are limited to the cost of modifying the applicable military specifications, manuals, and contracts required to implement the MPCD. Only costs associated with direct implementation of a MPCD option are included as initial costs. All initial costs for this discharge are incremental costs. The cost associated with repainting of underwater hulls is considered a routine maintenance action and is included as a recurring cost.

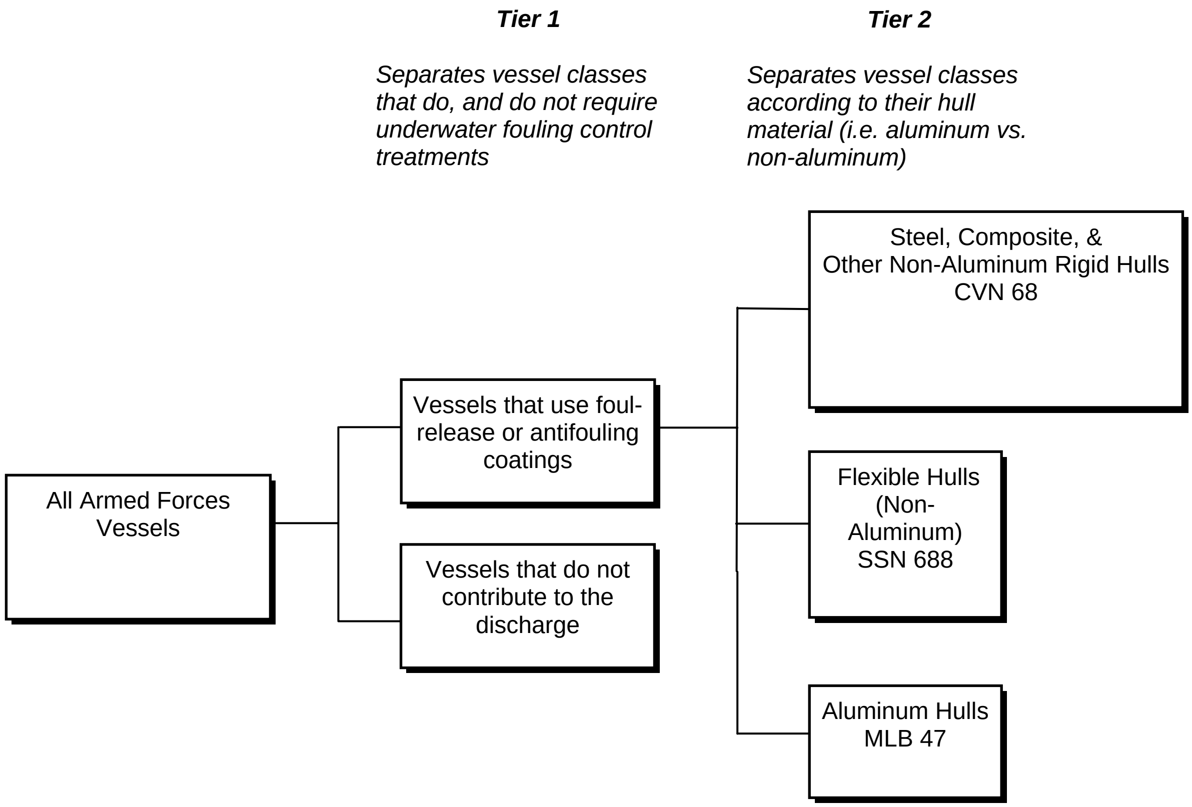
Recurring Costs: Recurring costs considered in the subsequent analyses include expenses for drydocking, labor, paint procurement, disposal, and other materials associated with repainting and waterborne hull cleaning. The cost and frequency of repainting are affected by the MPCD option. Some MPCDs do not result in additional recurring costs and the current costs are presented. For other MPCD options, recurring costs are presented for the current practice and the MPCD option as well as the cost increase (incremental costs) to use the MPCD option.

Total Ownership Costs: The total ownership cost (TOC) is a sum of the total initial and total recurring costs. The ACEIT model presents the cost estimate results as total initial, total recurring, and overall total cost expressed in 1999 dollars. ACEIT discounts the future costs (i.e., recurring cost) using discounted cash flow methodology to account for the time value of money. The cost analysis uses a discount rate of 3.2% that is based on real interest rates for 15-year Treasury Notes and Bonds (OMB, 1992). The future costs estimates are for the comparison of MPCD options only and are not intended for budget preparation.

1.2 Vessel Groups

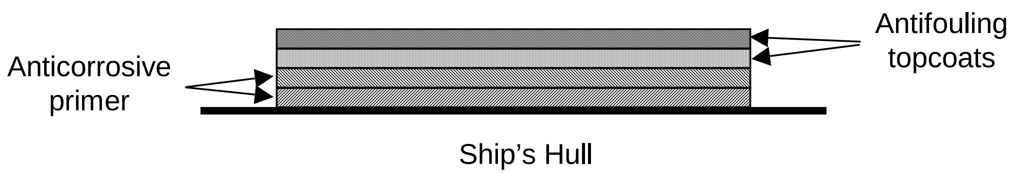
Vessels that produce hull coating leachate were sorted into three vessel groups using a tiered process as illustrated in Figure 1-1.

FIGURE 1-1. VESSEL GROUPING FUR HULL COATING LEACHATE DISCHARGE



The first tier segregates all Armed Forces vessels with coating systems (i.e., antifouling or foul-release coatings) to control fouling by marine organisms from those vessels that do not use coatings to control fouling. Most vessels of the Armed Forces use biocidal antifouling coating systems. However, boats and craft that spend most of their time out of water may be either unpainted or are painted with an epoxy or urethane anticorrosive coating. The epoxy anticorrosive coatings (primers) are also typically used under most antifouling topcoats as presented in Figure 1-2. Anticorrosive coatings do not contain biocides and do not produce hull coating leachate. Therefore, these coatings will not be analyzed in further sections of the FIAR, in the Characterization Analysis Report (ChAR), or in the Environmental Effects Analysis Report (EEAR). The second tier segregates aluminum hulls from non-aluminum hulls. Steel, composite, and other non-aluminum rigid hulls primarily use copper-containing antifouling coatings. These coatings are complex mixtures of resins, pigments (e.g., zinc oxide, iron oxides, carbon black, etc.), thickeners, and biocides such as cuprous oxide, copper thiocyanate, or other copper compounds that serve as biocides releasing copper when exposed to seawater). Aluminum hulls use copper-free antifouling coatings to avoid the risk of copper depositing on an exposed part of the aluminum hull and causing rapid pitting of the aluminum hull (ASM International, 1987; Jones, 1992; Lamtec, 2001). The second tier also segregates rigid hulls from flexible hulls. Vessels in the flexible hull group have steel hulls covered with a low-modulus elastomer to which antifouling coatings are applied. The flexible hull vessel group currently uses copper-containing antifouling coatings, but the Navy continues to search for more suitable coatings that are not as susceptible to cracking as the current copper-containing products. Further information regarding the vessel groups and selection of representative vessel classes is contained in the *Vessel Grouping and Representative Vessel Selection for Hull Coating Leachate Discharge* (Navy and EPA, 2003d).

FIGURE 1-2. Typical Antifouling Paint System



1.2.1 Steel, Composite, and Other Non-Aluminum Rigid Hulls

The steel, composite, and other non-aluminum rigid hull vessel group encompasses most Armed Forces vessels. There is considerable variability in size and design among vessels in this group. Vessels in this group range from small boats to aircraft carriers over 1,000 feet long. The main factor in grouping these vessels is that they predominately use copper-containing antifouling coatings. Although some vessels in this group may be able to use foul-release coatings, applicability of foul-release coatings is limited by the cost per gallon of the coatings, the three-year service life, product durability, and the effectiveness of the coatings on vessels ported in high fouling areas (e.g., ports in Hawaii and Florida). The USS NIMITZ (CVN 68) class of aircraft carrier was selected to perform the feasibility analyses because:

- as a vessel type, aircraft carriers have among the greatest wetted-hull surface area of this vessel group;
- all aircraft carriers use standard copper ablative coatings; and
- the CVN 68 Class vessels are still under construction and are expected to remain in service for decades.

1.2.2 Flexible (Non-Aluminum) Hulls

The flexible hulls vessel group consists of vessels that have hulls covered with flexible elastomeric materials painted with antifouling coatings. Current Navy technical guidance requires the use of copper-containing antifouling coatings listed in Class 3A (paint systems having antifouling topcoats containing only copper-based toxics for use on rubber) of specification MIL-PRF-24647. The flexible hulls vessel group includes 58 submarines distributed among three classes and the MCM 14, a mine countermeasure vessel in the USS AVENGER (MCM 1) class (Mine, 2002). The USS LOS ANGELES (SSN 688) class of attack submarines was selected as the representative vessel class for this group. This class has 51 submarines in service and comprises approximately 86% of the number of vessels in the group. Currently, copper ablative coatings are the primary antifouling coating used on this vessel group, but these coatings crack as a result of the elastomer compressing more than the antifouling coating system when the vessel dives to operating depth. The cracking of these coatings is an ongoing maintenance issue. The Navy has active efforts to identify antifouling coatings that are more flexible for use on flexible hulls.

1.2.3 Aluminum Hulls

The Aluminum Hulls vessel group includes numerous classes of smaller vessels used by the Armed Forces. Vessels with aluminum hulls include boats and craft ranging from less than 20 feet long to 192 feet in length. Armed Forces coating policy prohibits the use of copper-containing coatings on vessels in this group. Copper-containing coatings are not used on aluminum hulls to minimize the potential for deposition corrosion (see Section 4.1 for further explanation) at coating defects (ASM, 1987; Jones, 1992; Lamtec, 2001). Due to this prohibition on copper-containing coatings, craft in the Aluminum Hulls vessel group are coated with either foul-release coatings or coatings that use zinc-based and/or non-metallic biocides. The USCG's most recent motor lifeboat class, the MLB 47, was selected as the representative aluminum vessel because it is one of the larger Armed Forces vessels with an aluminum hull, is a relatively numerous vessel class (i.e., over 98 vessels are currently in service), and its operational parameters are consistent with the majority of aluminum craft operated by the Armed Forces.

1.3 MPCD Option Groups

The three hull coating leachate MPCD option groups that passed the screening process are listed below:

- Establish a Maximum Allowable Copper Leach Rate for Antifouling Coatings,
- Foul-Release Coatings, and
- Advanced Antifouling Coatings.

The MPCDs are evaluated for each of the aforementioned vessel groups identified.

The following sections provide a short overview of each option group. Additional details regarding these option groups are included in the respectively named hull coating leachate discharge MPCD screens (Navy and EPA, 2003a; Navy and EPA, 2003b; Navy and EPA, 2003c).

1.3.1 Establish a Maximum Allowable Copper Leach Rate for Antifouling Coatings

Antifouling coatings used on Armed Forces vessels are qualified under the military specification MIL-PRF-24647, Type I, Class 1A, 1B, and 3A. The copper compounds found in the antifouling coatings are used to prevent growth of marine fouling organisms. Under normal operating conditions, these coatings release copper into the surrounding water (Navy, 2001). This MPCD option group would establish a maximum allowable copper release rate for copper-containing antifouling coatings. It is anticipated that the use of a numerical copper release rate limit in conjunction with a standardized test method would allow the Armed Forces to minimize adverse effects to the marine environment while still attaining effective use of copper-containing antifouling coatings.

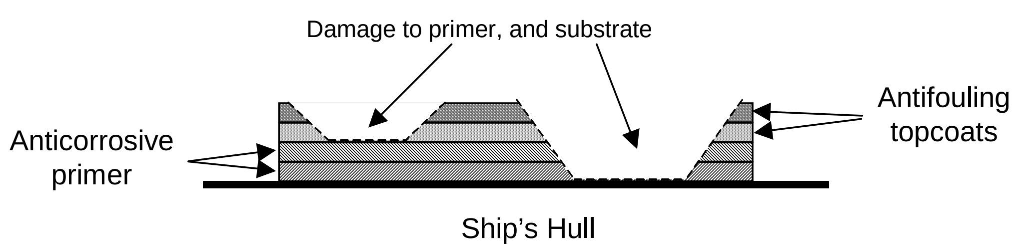
Once the maximum allowable copper release rate is established, the limit would be applied to current and future antifouling coatings. Coatings that emit more copper than allowed, as measured using the ASTM-D-6442 test method, would be prohibited from use on Armed Forces vessels.

1.3.2 Foul-Release Coatings

Foul-release hull coatings are typically soft, flexible materials based on silicone or urethane polymers that may use surfactants, surface textures, or surface chemistry to prevent fouling organisms from adhering to the hull coating. These soft, flexible coatings typically exhibit a low surface energy and are applied as extremely smooth layers such that any marine organisms that grow on the hull can be released or dislodged by the flow of water over the hull as the vessel achieves a critical speed (i.e., usually in excess of 15knots). Foul-release coatings do not discharge copper or other biocides into water.

Because foul-release coatings do not release biocides, marine-fouling organisms (e.g., algae, mollusks, worms, etc.) will grow on a coated hull while vessels are pierside. As little as two weeks of vessel inactivity (i.e., no instances of operations above the critical speed for fouling release) in high-fouling areas (e.g., subtropical and coastal environments) can result in significant build-up of marine fouling organisms on a vessel's hull (International Marine Coatings, 2001). Because motion is required to dislodge the marine fouling from the hull, ship speed is an important factor when considering the vessel classes or types that can successfully use foul-release coatings. Some coating vendors recommend foul-release coatings only for moderate and high activity ships that operate at average speeds of 15 knots or higher (International Marine Coatings, 2001; Hempel, 2001; Marlin Paint, 2001). When the vessel's operational profile does not provide sufficient operating time and speed to dislodge fouling organisms, underwater hull cleaning is usually required because the organisms are not removed any longer by vessel movement. Even careful cleaning of the soft, foul-release coatings can result in damage that could reduce their efficacy. Any scratches or abrasion can expose the epoxy primer or substrate metal under the foul-release coating as shown in Figure 1-3. These damaged areas will foul, and a more significant cleaning effort will be required to remove organisms from the epoxy substrate, resulting in more damage to the foul-release coating. Thus, even careful cleaning can result in rapid degradation in the performance of foul-release coating systems.

FIGURE 1-3. Damage to Foul-Release Coating System



Foul-release coatings are included in the requirements of military performance specification MIL-PRF-24647. These coatings are approved and used on a limited number of USCG and Navy vessels. Although no foul-release coating has demonstrated the ability to control fouling effectively for 12-years on Armed Forces vessels, one foul-release coating has been approved for use on selected Armed Forces craft (e.g., vessels with aluminum hulls, vessels with drydock cycles less than five years and vessels that have specialized acoustic performance requirements).

1.3.3 Advanced Antifouling Coatings

Advanced antifouling coatings release some form of biocide into the water surrounding the vessel hull to prevent the growth of marine fouling organisms. Some advanced antifouling coatings contain copper and a non-metallic co-biocide, while others are based on combinations of non-metallic biocides (i.e., metallic-biocide-free). Advanced antifouling coatings are currently being tested on Armed Forces vessels. The USCG has approved one metallic-biocide-free antifouling coating for use on smaller USCG vessels with aluminum hulls, *E Paint SN-1* (see below for details). The USCG-approved, metallic-biocide-free coating performs effectively for less than two years in high fouling areas such as Miami, FL. At present, advanced antifouling coatings have been shown to foul too quickly and do not satisfy the Navy performance requirements in MIL-PRF-24647 (Lawrence, 2003). In the case of advanced antifouling coatings that use copper as a biocide, the Navy has stated that the advanced antifouling coatings should emit less copper than is currently released from the copper-ablative products approved under MIL-PRF-24647 to be considered an environmentally acceptable product by the Navy (Ingle, 2002). This goal is intended to ensure that advanced antifouling coatings have a significantly reduced environmental impact when compared to currently approved copper ablative coatings. The Navy also established a copper release rate goal of zero for advanced antifouling coatings to ensure these products are even more environmentally acceptable than currently approved copper ablative coatings.

One advanced coating, *E Paint SN-1* produced by the E Paint Company, is approved by the USCG for use on USCG aluminum small boats and craft (USCG, 2000; Coatingsworld, 2002). *E Paint SN-1* is not approved for use by other services of the Armed Forces or larger USCG steel hulled vessels, because it has not been shown to meet minimum performance requirements for most vessels and has a service life of less than two years (Lawrence, 2003). The Navy has an active program to identify, test, and approve high performance advanced antifouling coatings for use on vessels with a 12-year docking cycle.

2.0 FEASIBILITY ANALYSIS - STEEL, COMPOSITE, AND OTHER NON-ALUMINUM RIGID HULLS

The feasibility of implementing the three MPCD options for the steel, composite, and other non-aluminum rigid hulls vessel group is assessed in the following sections. The steel, composite, and other non-aluminum rigid hulls vessel group is the largest vessel group in the hull coating leachate discharge. Approximately 2,600 vessels are included in this group, which accounts for 87% of the vessels that produce hull coating leachate discharge.

2.1 Establish a Maximum Allowable Copper Release Rate for Antifouling Coatings

The MPCD option to establish a maximum copper release rate for antifouling coatings is based on examining copper release rates from current coatings, using these data to develop a numerical limit, and then applying the numerical limit to all current and future antifouling coatings adopted for use on Armed Forces vessels. For the purpose of this analysis, release rates from the ablative copper coatings used on the vast majority of Armed Forces vessels are used for developing numerical limits. This MPCD option is referred to as the “maximum copper standard” in subsequent sections (Navy and EPA, 2003a).

2.1.1 Practicability and Operational Impact Analysis

The practicability and operational impact of the MPCD option are addressed in the following subsections. Feasibility factors are addressed only to the extent necessary to support comparison to other MPCD options in subsequent sections.

2.1.1.1 Mission Capabilities

Copper ablative coatings currently qualified to MIL-PRF-24647 requirements are the basis for this MPCD. Therefore, mission capabilities are not impacted and further discussion is not required.

2.1.1.2 Drydocking Interval and Pierside Maintenance

The USS NIMITZ class is on a 12-year drydocking cycle based on long range maintenance and operational requirements. The underwater hull is cleaned by divers several times between each drydocking on an as-needed basis to meet this service requirement (McCue, 2003a). Historical information reveals these underwater hull cleanings occur every 40 to 48 months, which results in approximately three hull cleanings between each drydocking. A typical maintenance cycle for a USS NIMITZ class vessel is shown in Table 2-1 (Navy and EPA, 2003e).

Table 2-1 Typical Maintenance Cycle for Copper Ablative Coatings on a USS NIMITZ Class Vessel

Activity	Timeline (months)
Undock	0
Hull Cleaning	46
Hull Cleaning	86
Hull Cleaning	116
Drydock and Repaint	144

2.1.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

2.1.2.1 Initial Costs

Initial costs for the MPCD option are estimated to include writing, obtaining public comment on, and publishing modified versions of Military Specification MIL-PRF-24647, NAVSEA Standard Item 009-32, Naval Ship Technical Manual Chapter 631, and the USCG Coatings and Color Manual to include a maximum copper release rate. Only costs associated with direct implementation of a MPCD option are included as initial costs. Cost estimates for updating these specifications are presented in Table 2-2 (Navy, 2003).

Table 2-2—Initial Cost of Implementing the Maximum Copper Standard for the Steel, Composite, and Other Non-Aluminum Rigid Hulls Vessel Group

Specification Modified	Cost estimate ($K, in 1999 dollars)
Navy NSTM Chapter 631	12
Navy MIL-PRF-24647	12
NAVSEA Standard Item 009-32	6
USCG: Coatings and Color Manual	12
Total	**42**

The cost includes labor to develop and draft changes to existing specifications and manuals. Additional costs are not expected for the implementation of this MPCD option. This MPCD option does not affect the present qualified list of products; therefore, other military specifications are not addressed.

2.1.2.2 Recurring Costs

This MPCD results in no change from the currently used coatings. Therefore, recurring costs are the current cost for drydocking, re-preservation (coating removal, surface preparation, and repainting), and underwater hull cleaning. The recurring costs for repainting the underwater hull of a USS NIMITZ class vessel were determined from a Newport News Shipyard Feasibility Study of Hull Preservation Systems report (Shimko, 1998).

The cost for re-preservation of the underwater hull of a CVN 68 class vessel is estimated to be $1,400,000, which includes old coating removal, surface preparation, paint procurement, quality assurance requirements, solid waste disposal, and other material costs. Re-preservation costs are estimated to be incurred once every 12 years.

The cost to dock and undock a USS NIMITZ class vessel is estimated at $2,200,000 (Hess, 2001). This cost does not include re-preservation efforts or any other work done while in drydock. A four-week drydocking period is estimated for re-preservation.

Based on a historical review of shipboard information, the cost of waterborne underwater hull cleaning for a USS NIMITZ class vessel is estimated to be $68K per cleaning every 40 to 48 months (McCue, 2003a). Three cleanings are estimated for each 12-year drydocking interval.

Recurring costs over a 12-year interval for current ablative coatings on a USS NIMITZ Class vessel are summarized in Table 2-3.

Table 2-3—Recurring Costs of using Current Copper Ablative Coatings on a USS NIMITZ Class Vessel

Cost Item	**Number of Operations**	**Copper Ablative Coatings (Current Practice)** ($K, in 1999 dollars**)**
Re-preservation	1	
Cost per Operation		1,400
Cost Over 12-year Period		1,400
Drydockings	1	
Cost per Drydocking		2,200
Cost Over 12-year Period		2,200
Hull Cleaning	3	
Cost per Cleaning		68
Cost Over 12-year Period		200
Total Recurring Costs - Over 12-year Period per Vessel		**3,800**
Total Recurring Costs – Annual Basis per Vessel		**320**

Vessels within the steel, composite, and other non-aluminum rigid hulls vessel group range significantly in size and mission resulting in variability in the costs shown. These costs are not intended to be representative of the entire vessel group. Fleetwide costs are presented in the Discharge Assessment Report.

2.1.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the Maximum Copper Standard are presented in Table 2-4.

Table 2-4—Total Ownership Costs of the Maximum Copper Standard for a USS NIMITZ Class Vessel

Cost Item	Cost ($K, in 1999 dollars)
Total Initial	$42
Total Recurring	$3,800
TOC - 12-year Period	$3,571
Annualized	**$298**

2.2 Foul-Release Coatings

The feasibility of using foul-release coatings for the steel, composite, and other non-aluminum rigid hulls vessel group is discussed in subsequent sections. Foul-release coatings contain no biocides, and as such, do allow marine organisms to grow on the hull. However, these coatings rely on the flow of water across the hull or on hull cleaning to remove any fouling that does grow on the hull during periods of inactivity. The foul-release coating, International Intersleek 425, is the basis for all analyses. Intersleek 425 is approved for use on selected Armed Forces craft (e.g., vessels with aluminum hulls, vessels with drydock cycles less than five years, and vessels that have specialized acoustic performance requirements).

2.2.1 Practicability and Operational Impact Analysis

A discussion of the practicability and operational impact of using foul-release coatings on a USS NIMITZ class vessel is presented in the following sections.

2.2.1.1 Mission Capabilities

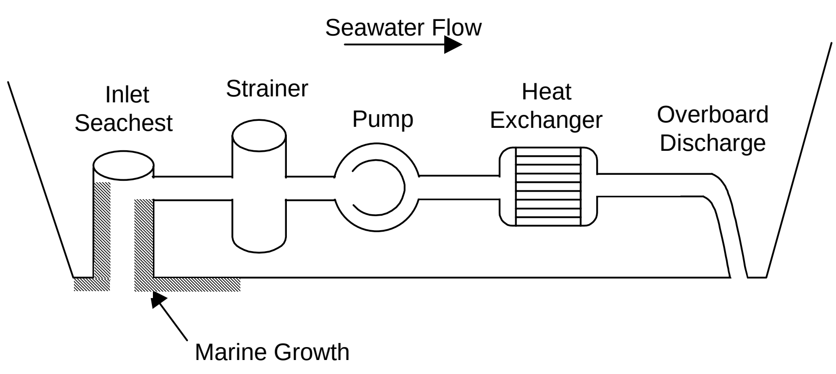
Although foul-release coatings have been shown to be effective at controlling fouling on some commercial craft (e.g., ferries) (International Marine Coatings, 2001), key variations in mission, design, and operating tempo between military and commercial craft can limit the viability of foul-release coatings on Armed Forces vessels. The factors that limit the viability of foul-release coatings for use on military vessels are operational cycle and coating durability.

The operating cycle of Armed Forces craft is different than that of the vessels upon which foul-release coatings have proven effective. Armed Forces vessels typically remain pierside more than 50% of the time, while commercial craft that use foul-release coatings are typically pierside 15% of the time. During periods of inactivity, Armed Forces hulls coated with foul-release coatings grow larger and more tenacious fouling colonies. Therefore, the Navy and USCG have found that more hull cleanings are required prior to departing for missions to avoid fouling-induced degradation of a vessel's speed and range (Navy and EPA, 2003b). For example, as little as two weeks of vessel inactivity (i.e., no instances of operations above the critical speed for fouling release) in high-fouling areas can result in significant build-up of marine fouling organisms on a vessel's hull (International Marine Coatings, 2001). As a result, Armed Forces vessels with foul-release coatings must either conduct more frequent hull cleanings or risk being declared mission incapable (Dust, 2003d).

Main Propulsion and Auxiliary Systems

The operation of a vessel's main propulsion and auxiliary systems are assumed to be impacted by the use of foul-release coatings on the vessel's underwater hull because of the risk of fouling organisms being drawn into seawater systems. Large sea chests, usually greater than 6-inches in diameter, are typically painted with the hull antifouling paint system. Foul-release coatings applied to the sea chests will allow fouling organisms to grow when the seawater system is not in operation. When the seawater system is put into operation, growth in the sea chest and on the nearby hull area can be drawn into the seawater system. Additional maintenance is assumed to be necessary for the seawater systems because the increased need for sea chest, strainer and heat exchanger cleaning (McCue, 2003b). Strainers are estimated to require cleaning several times per hour after system start-up until marine growth in the sea chest and surrounding hull area has been removed by the flow of seawater into the ship. Figure 2.1 shows a schematic of a sea chest and the associated seawater cooling system. Therefore, the ability for fouling to grow on the inside of the sea chest and underwater hull when biocidal antifouling coatings are not used can be easily inferred. Additionally, a reduction in the efficiency of the heat exchangers due to partially clogged cooling water tubes is possible if all growth is not removed by strainers. In extreme cases, a seawater system shutdown is required to open and clean heat exchangers to restore system operation. The reduced efficiency of seawater cooling systems has a significant impact on the vessel's mission performance. These systems support main propulsion, power generation, radars, and weapons systems.

FIGURE 2-1. Typical Seawater System



Finally, the inherent mission of Armed Forces craft can limit the effectiveness of foul-release coatings when compared to the effectiveness of these products on commercial craft. Foul-release coatings are inherently soft and easily damaged by any form of abrasion or vigorous cleaning. The limited durability of foul-release coatings combined with the generally longer drydock cycles and increased opportunities for coating damage inherent with Armed Forces vessels, when compared to commercial craft, limit the applicability of foul-release coatings in the Armed Forces. For example, some Armed Forces craft (e.g., landing craft, USCG buoy maintenance craft, etc.) regularly operate in shallow water and actually abrade coatings by direct contact with sand and other sediments. Foul-release coatings applied to commercial vessels that unintentionally run aground are damaged to the extent that the vessel must be drydocked and recoated. Armed Forces also regularly operate in northern waters that may contain ice or debris that can damage foul-release coatings and degrade coating service life (USCG, 2000). For example, USCG vessels based north of the Chesapeake Bay generally do not use foul-release coatings, because ice has damaged foul-release coatings in these regions in the past. Thus, the impact with sediment and ice, inherent in Armed Forces vessel operating profile, limits the usefulness of foul-release coatings on Armed Forces craft.

The most significant difference in the operational profile between Armed Forces and commercial vessels that limits the usefulness of foul-release coatings is the time between drydockings and the time spent pierside by Armed Forces vessels. Even with the little time spent pierside, commercial craft coated with the soft foul-release coatings may be damaged by contact with fenders and tugs. In fact, some commercial craft that use foul-release coatings actually apply a copper-containing coating to the side-shell and boot-top areas to avoid damage to the foul-release coating when moored to piers (International, 2003). With an increase in the time spent pierside, the damage to the boot-top region on Armed Forces craft would be even more pronounced than on commercial craft. In addition, commercial craft generally do not conduct waterborne underwater hull cleaning. Armed Forces craft do conduct underwater hull cleanings; and therefore, the damage caused by this process is unique to Armed Forces vessels. Every time a foul-release coating is cleaned, the scouring action of the cleaning device, combined with the hard fragments of the organism shells being removed, will cause scratches in the soft foul-release coating. As previously shown in Figure 1-2, these scratches expose anticorrosive primer which creates sites for fouling growth that will adhere more tenaciously to the primers, resulting in an increase in the frequency and difficulty of future cleaning. This rapid downward spiral toward coating ineffectiveness due to cleaning is unique to Armed Forces craft using foul-release coatings.

2.2.1.2 Drydocking Interval and Pierside Maintenance

The impact of this MPCD option on drydocking interval and pierside maintenance is discussed as a single factor because the frequency of underwater hull cleaning is related to the drydocking interval.

USS NIMITZ class vessels are currently coated with copper ablative antifouling coatings that support a drydocking every 12 years and require cleaning approximately every 40 to 48 months. Navy experience with foul-release coatings on MCM vessels has demonstrated that cleanings are required every six months, while USCG experience on smaller craft indicate cleaning is required as frequently as every two weeks in tropical areas (Navy and EPA, 2003e; Dust, 2003d). Similarly, foul-release coatings are assumed to have a three-year service life based on existing fleet experience (USCG, 2000). From these frequencies, a hypothetical maintenance cycle was developed. A comparison of the maintenance cycle for foul-release and current copper ablative coatings for a USS Nimitz Class Vessel is presented in Table 2-5.

Table 2-5—Comparison of the Hypothetical Maintenance Cycle for Foul-Release and Copper Ablative Coatings on a USS NIMITZ Class Vessel

Activity	Timeline (months)	
	Copper Ablative Coatings (Current Practice)	Foul-Release Coatings
Undock	0	0
Hull Cleaning	46	6
	86	12
	116	18
		24
		30
Drydock and Repaint	144	36

As shown in Table 2-5, the use of foul-release coatings is estimated to result in a significant increase in the frequency of both hull cleanings and drydockings. A comparison of the number of pierside maintenance activities is presented in Table 2-6. Over a 12-year period, a vessel using foul-release coatings is estimated to require three additional drydockings and 17 additional hull cleanings.

Table 2-6—Pierside Maintenance Activities Over a 12-year Interval for Foul-Release and Copper Ablative Coatings on a USS NIMITZ Class Vessel

Activity	Number of Estimated Activities Over a 12-Year Interval	
	Copper Ablative Coatings (Current Practice)	Foul-Release Coatings
Dock/Repaint/Undock	1	4
Hull Cleaning	3	20

2.2.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

2.2.2.1 Initial Costs

Initial costs for the foul-release MPCD option are estimated for the editorial changes and processing required to update existing Navy and USCG military specifications for coatings and coating supply contracts for the Army, Military Sealift Command (MSC), and Air Force. Table 2-7 presents an estimate of the specifications and contracts that require updating and the associated costs.

Table 2-7—Initial Cost of Implementing the Foul-Release Coatings MPCD for the Steel, Composite, and Other Non-Aluminum Rigid Hulls Vessel Group

Specification Modified	**Cost Estimate** ($K , in 1999 dollars)
Navy NSTM Chapter 631	12
Navy MIL-PRF-24647	0
NAVSEA Standard Item 009-32	6
USCG Coatings and Color Manual	12
Army Contract	6
MSC Contract	6
Air Force Contract	6
Total:	**48**

The cost includes the labor to develop and draft changes to existing specifications, manuals, and contacts. Performance data and criteria are assumed to exist to support the updating of the military specification. Additional costs are necessary if development and evaluation of coating performance standards is required.

2.2.2.2 Recurring Costs

Recurring costs include expenses for drydocking, re-preservation, and hull cleaning. Costs associated with additional shipboard maintenance (i.e., cleaning sea chests, seawater strainers, and heat exchangers) are not included.

Re-preservation costs include labor, paint procurement, solid waste disposal, and other material costs. Foul-release coatings at $350 per gallon are significantly more expensive to procure than copper ablative coatings with an approximate cost of $35 to $40 per gallon. In addition, the shorter drydocking cycle and increased painting frequency will increase the amount of paint required over the life of the vessel. The cost of other materials (i.e., abrasive grit, cleaners, and consumables) and labor are estimated to increase by 10% to account for dedicated lines, additional cleaning of equipment, and masking requirements. Understanding that foul release coatings are not currently recommended for use on the CVN 68 class, the theoretical total estimated re-preservation cost for a USS NIMITZ class vessel is estimated to increase from $1,400,000 to $2,100,000 based on USCG cost comparison of several antifouling systems (USCG, 2000).

The cost to dock and undock a USS NIMITZ class vessel is estimated at $2,200,000. A four-week drydocking period is estimated for re-preservation.

The cost of underwater hull cleaning a vessel with a foul-release coating is estimated at $34K per cleaning. This is estimated at half of the cost required for vessels painted with more conventional antifouling coatings, because less effort is required to remove marine growth (USCG, 2000). These cost savings are also highly time dependent. For example, the first cleaning of a foul-release coating will be relatively inexpensive. However, as the coating ages and accumulates abrasion damage, the cleaning costs will increase due to increased cleaning frequency and increased fouling.

Recurring costs over a 12-year interval for the hypothetical use of the foul-release coating MPCD option on a USS NIMITZ Class vessel are summarized in Table 2-8.

Table 2-8—Recurring Costs of the Foul-Release Coatings MPCD for a USS NIMITZ Class Vessel

Cost Item	Copper Ablative Coatings (Current Practice)		Foul Release Coatings		Incremental Cost For Use of Foul-Release Coatings	
	Number of Operations	Cost ($K, in 1999 dollars)	Number of Operations	Cost ($K, in 1999 dollars)	Number of Operations	Cost ($K, in 1999 dollars)
Re-preservation	1		4		3	
Cost per Operation		1,400		2,100		700
Cost Over 12-year period		1,400		8,400		7,000
Drydockings	1		4		3	
Cost per Drydocking		2,200		2,200		0
Cost Over12-year Period		2,200		8,800		6,600
Hull Cleaning	3		20		17	
Cost per Cleaning		68		34		(34)
Cost Over 12-year Period		200		680		480
Total Recurring Costs – Over 12-year Period per Vessel		**3,800**		**18,000**		**14,000**
Total Recurring Costs – Annual Basis per Vessel		**320**		**1,500**		**1,200**

Vessels within the steel, composite, and other non-aluminum rigid hulls vessel group range significantly in size and mission resulting in variability in the costs previously shown. These costs are not intended to be representative of the entire vessel group. Fleetwide costs are presented in the Discharge Assessment Report.

2.2.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the Foul-Release Coatings MPCD are presented in Table 2-9.

Table 2-9—Total Ownership Costs for the Foul-Release Coatings MPCD for a USS NIMITZ Class Vessel

Cost Item	**Cost** ($K, in 1999 dollars)
Total Initial	48
Total Recurring	18,000
TOC – 12-year Period	16,763
Annualized	**1,397**

2.3 Advanced Antifouling Coatings

The feasibility of using advanced antifouling coatings for the steel, composite, and other non-aluminum rigid hulls vessel group is discussed in subsequent sections. Advanced antifouling coatings reduce the discharge of metals when compared to currently approved ablative coatings through the use of non-metallic biocides that typically exhibit a short half-life in the marine environment. The advanced antifouling coating, *E Paint SN-1,* is the basis for all analyses.

One advanced coating, *E Paint SN-1* produced by the E Paint Company, is currently approved by the USCG for use on USCG aluminum small boats and craft, but is not approved for use on larger USCG steel hulled vessels (USCG, 2000; Coatingsworld, 2002). In addition, *E Paint SN-1* has not met the minimum performance requirements of military specification MIL-PRF-24647 and is not authorized for use on Navy vessels.

2.3.1 Practicability and Operational Impact Analysis

A discussion of the practicability and operational impact of using advanced antifouling coatings on a USS NIMITZ class vessel is presented in the following sections.

2.3.1.1 Mission Capabilities

E Paint SN-1 has been shown to be effective at controlling fouling for an estimated service life of one to two years, with supplemental hull cleanings (USCG, 2000; Navy and EPA, 2003c). However, key variations in mission, operating tempo, and maintenance schedules between military and commercial craft can limit the viability of *E Paint SN-1* on Armed Forces vessels.

The hulls of vessels that use currently approved advanced antifouling coatings quickly become fouled after the first year of service as the active biocide is depleted, necessitating more frequent hull cleanings to reduce the impact on a vessel's speed and range. After the first year of service, it is assumed hull cleanings are required prior to departing for missions to reduce or eliminate impact on a vessel's speed and range (USCG, 2000). Even with frequent hull cleanings, E Paint SN-1 is estimated to have a maximum service life of only two years, resulting in the need to dock and repaint the vessel at least every two years (USCG, 2000).

Main Propulsion and Auxiliary Systems

The operation of a vessel's main propulsion and auxiliary systems are assumed to be impacted by the use *E Paint SN-1* on the vessel's underwater hull because of the risk of fouling being drawn into and clogging the seawater systems. Large sea chests, usually greater than six inches in diameter, are typically painted with the hull antifouling paint system. After the first year of service when the active biocide is depleted, *E Paint SN-1* applied to the sea chests is assumed to enable the growth of fouling organisms when the seawater system is not in operation. Fouling will quickly grow not only on the hull, but in sea chests that service seawater cooling systems as shown previously in Figure 2-1. When the seawater system is put into operation, growth of fouling organisms in the sea chest and on the nearby hull area is drawn into the seawater system. Additional maintenance is assumed to be necessary for the seawater systems because the increased need for strainer and heat exchanger cleaning. Once the system starts up, strainers are estimated to require cleaning several times per hour until marine growth in the sea chest and surrounding hull area has been removed by the flow of seawater into the ship. In addition, if all growth is not removed by the strainers, it is possible that heat exchangers lose efficiency due to partially clogged cooling water tubes. In extreme cases, a seawater system shutdown is required to open and clean heat exchangers to restore system operation. The reduced efficiency of seawater cooling systems has a significant impact on the vessel's mission performance. These systems support main propulsion, power generation, radars, and weapons systems.

2.3.1.2 Drydocking Interval and Pierside Maintenance

The impact of this MPCD option on drydocking interval and pierside maintenance is discussed as a single factor because the frequency of underwater hull cleaning and pierside maintenance is related to the drydocking interval.

USS NIMITZ class vessels are currently drydocked every 12 years and cleaned approximately every 40 to 48 months. The use of advanced antifouling coatings is estimated to require a significant increase in the frequency of hull cleanings and drydocking due to the limited service life of these coatings. For the purpose of this analysis, hull cleanings are estimated to be required every six months after the first year of service. Similarly, the estimated two-year service life of advanced antifouling coatings is based on existing fleet experience with these coatings (USCG, 2000). From these frequencies, a hypothetical maintenance cycle is developed. A comparison of the maintenance cycle for advanced antifouling coatings and current copper ablative coatings is provided in Table 2-10.

Table 2-10—Comparison of the Maintenance Cycle for Advanced Antifouling and Copper Ablative Coatings on a USS NIMITZ Class Vessel

Activity	Timeline (months)	
	Copper Ablative Coatings (Current Practice)	**Advanced Antifouling Coatings**
Undock	0	0
Hull cleaning	46	12
	86	18
	116	
Drydock and repaint	144	24

As shown in Table 2-12, the use of advanced antifouling coatings is estimated to result in a significant increase in the frequency of both hull cleaning and drydocking. A comparison of the number of pierside maintenance activities is presented in Table 2-11. Over a 12-year period, a vessel using advanced antifouling coatings is estimated to require five additional drydockings and nine additional hull cleanings.

Table 2-11—Pierside Maintenance Activities Over a 12-year Interval for Advanced Antifouling Coatings and Copper Ablative Coatings on a USS NIMITZ Class Vessel

Activity	Number of Estimated Activities Over a 12-Year Interval	
	Copper Ablative Coatings (Current Practice)	**Advanced Antifouling Coatings**
Dock/Repaint/Undock	1	6
Hull Cleaning	3	12

2.3.2 Cost Analysis Factors

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

2.3.2.1 Initial Costs

Initial costs for the advanced antifouling MPCD option are estimated for preparing specification edits, obtaining public comments, and promulgating changes to existing Navy and USCG military specifications for coatings and coating supply contracts for the Army, MSC, and Air Force (Navy, 2003). An estimate of the specifications and contracts that require updating and the associated costs are presented in Table 2-12.

Table 2-12—Initial Cost of Implementing the Advanced Antifouling Coatings MPCD for the Steel, Composite, and Other Non-Aluminum Rigid Hulls Vessel Group

Specification or Contract Modified	**Cost estimate** ($K, in 1999 dollars)
Navy NSTM Chapter 631	12
Navy MIL-PRF-24647	25
NAVSEA Standard Item 009-32	6
USCG Coatings and Color Manual	12
Army Contract	6
MSC Contract	6
Air Force Contract	6
Total:	**73**

The cost includes the labor to develop and draft changes to existing specifications, manuals, and contacts. Performance data and criteria are assumed to exist to support the updating of the military specification. The cost for modifying MIL-PRF-24647 is estimated to be greater than other MPCD options, because advanced antifouling coatings are not currently approved for use on Navy vessels. Additional costs are necessary if development and evaluation of coating performance standards are required.

2.3.2.2 Recurring Costs

Recurring costs include expenses for drydocking, re-preservation and hull cleaning. Costs associated with additional shipboard maintenance (i.e., cleaning sea chests, seawater strainers, and heat exchangers) are not included.

Re-preservation costs include labor, paint procurement, solid waste disposal, and other material costs. Advanced antifouling coatings at $140 per gallon are significantly more expensive to procure than copper ablative coatings with an approximate cost of $35 - $40 per gallon. The shorter drydocking cycle and increased painting frequency increases the quantity of paint required over the life of the vessel. This cost of other materials (i.e., abrasive grit, cleaners, and consumables) and labor are assumed to be unchanged. The total re-preservation cost per vessel is estimated to increase from $1,400,000 to $1,600,000 based on USCG cost comparison of several antifouling systems (USCG, 2000).

The cost to dock and undock a USS NIMITZ class vessel is estimated at $2,200,000. A four-week drydocking period is estimated for re-preservation.

The cost of underwater hull cleaning a vessel with advanced antifouling coatings is estimated at $68,000, which is similar to the cost for vessels painted with copper ablative antifouling coatings. Fouling organisms are estimated to require the same amount of effort for removal on either coating.

Understanding that advanced antifouling coatings are not currently approved for use on the CVN 68 class, the theoretical recurring costs over a 12-year interval for the advanced antifouling coating MPCD option on a USS NIMITZ class vessel are summarized in Table 2-13.

Table 2-13—Recurring Costs of the Advanced Antifouling Coatings MPCD for USS NIMITZ Class Vessel

Cost Item	Copper Ablative Coating (Current Practice)		Advanced Antifouling Coating		Incremental Cost For Use of Advanced Antifouling Coatings	
	Number of Operations	Cost ($K, in 1999 dollars)	Number of Operations	Cost ($K, in 1999 dollars)	Number of Operations	Cost ($K, in 1999 dollars)
Re-preservation	1		6		5	
Cost per Operation		1,400		1,600		200
Cost Over 12-year Period		1,400		9,600		8,200
Drydockings	1		6		5	
Cost per Drydocking		2,200		2,200		0
Cost Over 12-year Period		2,200		13,200		11,000
Hull Cleaning	3		12		9	
Cost per Cleaning		68		68		0
Cost Over 12-year Period		200		820		620
Total Recurring Costs – Over 12-Year Period per Vessel		**3,800**		**23,620**		**19,800**
Total Recurring Costs – Annual Basis per Vessel		**300**		**1,970**		**1,670**

Vessels within the steel, composite, and other non-aluminum rigid hulls vessel group range significantly in size and mission resulting in variability in the costs previously shown. These costs are not intended to be representative of the entire vessel group. Fleetwide costs are presented in the Discharge Assessment Report.

2.3.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the advanced antifouling coatings MPCD are presented in Table 2-14.

Table 2-14—Total Ownership Costs for the Advanced Antifouling Coatings MPCD for a USS NIMITZ Class Vessel

Cost Item	**Cost** ($K, in 1999 dollars)
Total Initial	73
Total Recurring	23,620
TOC – 12-year Period	22,007
Annualized	**1,834**

3.0 FEASIBILITY ANALYSIS – FLEXIBLE (NON-ALUMINUM) HULLS

The feasibility of implementing three MPCD options for the flexible (non-aluminum) hulls vessel group is assessed in the following sections. This is the smallest vessel group in the hull coating leachate discharge in terms of the number of vessels per group. The flexible (non-aluminum) hulls vessel group consists of 59 vessels, which accounts for 2% of the vessels that produce hull coating leachate discharge. Only Navy vessels are included in this group.

3.1 Establish a Maximum Allowable Copper Release Rate for Antifouling Coatings

The MPCD option to Establish a Maximum Copper Release Rate for Antifouling Coatings is based on testing copper ablative coatings approved to MIL-PRF-24647. Using these coatings is the standard practice for this vessel group (Navy and EPA, 2003a). This MPCD option is referred to as the Maximum Copper Standard in subsequent sections.

3.1.1 Practicability and Operational Impact Analysis

The practicability and operational impact of the MPCD option are addressed in the following subsections. Feasibility factors are addressed only to the extent necessary to support comparison to other MPCD options in subsequent sections.

3.1.1.1 Mission Capabilities

Currently used copper ablative coatings are the basis for this MPCD option. Therefore, mission capabilities are not impacted and further discussion is not required.

3.1.1.2 Drydocking Interval and Pierside Maintenance

The representative vessel, USS LOS ANGELES (SSN 688), is on a 2.5-year drydocking cycle based on long-range maintenance and operational requirements. The hull is cleaned by divers several times between each drydocking on an as needed basis to meet this service requirement (McCue, 2003a). Historical information reveals these underwater hull cleanings occur every eight months, on average, which results in approximately three hull cleanings between each drydocking. A typical maintenance cycle for a USS LOS ANGELES Class vessel is shown in Table 3-1.

Table 3-1—Typical Maintenance Cycle for Current Copper Ablative Coatings on a USS LOS ANGELES Class Vessel

Activity	Timeline (months)
Undock	0
Hull cleaning	8
Hull cleaning	16
Hull cleaning	24
Drydock and repaint	30

Submarines are cleaned more frequently in comparison to other DoD vessels due to noise considerations, the unique hull form, and the susceptibility of ablative antifouling coatings to crack when applied to flexible substrates. Hull fouling increases the noise generated by the vessel as it moves through the water and disrupts sonar performance. As a result, submarines need frequent cleanings to ensure sonars perform effectively and self-generated noise is minimized. Submarines also need more frequent cleanings because the portion of the hull above mean maximum beam is still immersed in seawater and creates a shallow, warm area with abundant exposure to sunlight that allows rapid algae growth. Frequent cleanings are needed to remove the resulting algae. Because the copper ablative coatings are more brittle than the elastomer on submarine hulls, the coatings tend to crack, degrading service life. Irregularities along the painted surfaces increase fouling, as shown previously in Figure 1-2, which also necessitates more frequent hull cleaning for the SSN 688 class.

3.1.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

3.1.2.1 Initial Costs

Initial costs for the MPCD option are estimated for modifying Navy Submarine Maintenance Manual, Military Specification MIL-PRF-24647, and NSTM Chapter 631 to include a maximum copper release rate. NAVSEA Standard Item 009-32 ("Preservation of Ships") is not used to support submarine maintenance. Cost estimates for updating these specifications are presented in Table 3-2 (Navy, 2003).

Table 3-2—Initial Cost of Implementing the Maximum Copper Standard for the Flexible Hulls Vessel Group

Specification Modified	**Cost estimate** ($K, in 1999 dollars)
Navy Submarine Maintenance Manual	12
Navy NSTM Chapter 631	12
Navy MIL-PRF-24647	12
Total:	**36**

The cost includes labor to develop and draft changes to existing specifications and manuals. No additional costs are expected for the implementation of this MPCD option. This vessel group does not impact USCG, Army, MSC, and Air Force vessels.

3.1.2.2 Recurring Costs

This MPCD results in no change from currently used coatings. Therefore, recurring costs are the current cost for drydocking, re-preservation, and underwater hull cleaning.

The recurring costs for repainting the hull of the representative vessel class were based on cost information presented in Section 2. Using a constant cost per unit area, the cost for re-preservation of an SSN 688 class vessel is estimated to be $310,000, which includes old coating removal, surface preparation, paint procurement, application, quality assurance requirements, solid waste disposal, and other material costs. Re-preservation costs are incurred once every 2.5 years.

The cost to dock and undock the representative vessel is estimated at $950,000.

The cost of waterborne hull cleaning for the representative class is estimated to be $17,000 per cleaning. Three cleanings are estimated for each 2.5-year drydocking interval (McCue, 2003a).

Recurring costs over a 12-year interval for the current ablative coating on a USS LOS ANGELES class vessel are summarized in Table 3-3.

Table 3-3—Recurring Costs of Current Ablative Coatings for the USS LOS ANGELES Class Vessel

Cost Item	Number of Operations	Copper Ablative Coatings (Current Practice) ($K, in 1999 dollars)
Re-preservation	4	
Cost per Operation		310
Cost Over 12-year interval		1,200
Drydockings	4	
Cost per Drydocking		950
Cost Over 12-year Period		3,800
Hull Cleanings	15	
Cost per Cleaning		17
Cost Over 12-year Period		260
Total Recurring Costs – Over 12-year Period per Vessel		**5,260**
Total Recurring Costs – Annual Basis per Vessel		**440**

3.1.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the Maximum Copper Standard are presented in Table 3-4.

Table 3-4—Total Ownership Costs of the Maximum Copper Standard for a USS LOS ANGELES Class Vessel

Cost Item	**Cost** ($K, in 1999 dollars**)**
Total Initial	36
Total Recurring	5,260
TOC - 12-year Period	4,921
Annualized	**410**

3.2 Foul-Release Coatings

The feasibility of using foul-release coatings for the flexible hulls vessel group is discussed in this section. Foul-release coatings, which do not contain biocides, minimize fouling organism adhesion to the hull. Marine organisms that grow on the hull may be dislodged by the flow of water across the hull or by hull cleaning. The foul-release coating used as a basis for all analyses is International Intersleek 425, which has been approved for use on selected Armed Forces craft (e.g., vessels with aluminum hulls, vessels with drydock cycles less than five years, and vessels that have specialized acoustic performance requirements).

3.2.1 Practicability and Operational Impact Analysis

A discussion of the practicability and operational impact of using foul-release coatings on the representative vessel class is presented in the following sections.

3.2.1.1 Mission Capabilities

Hulls coated with foul-release coatings are expected to become more fouled, as compared to anti-fouling coatings, when sitting pierside for extended periods. Depending upon the age of the coating, this fouling may be dislodged by attaining a minimum speed (this speed is currently unknown and depends upon the coating's condition) however, at some point in the coating's life, cleaning would be necessary. Submarines cannot deploy with a fouled hull because this will increase the vessel's self-generated noise and degrade the ability of the vessel to perform its mission.

In addition, although fouling generally occurs while a vessel is stationary vice underway, flexible hull vessels may be on station for several weeks at slow speeds. These vessels operate in nutrient-rich littoral waters; these conditions may allow fouling organisms to attach and grow, thereby increasing self-generated noise until the vessel is cleaned or attains sufficient speed to dislodge the fouling organisms. When deployed, the need for high speed runs or for cleaning of the hull would degrade the vessel's availability and ability to perform its mission.

The limited durability of foul-release coatings would prevent their use on submarines deployed to specific geographic regions. For example, transit through areas with sediment, debris, or ice can damage the coating and result in loss of coating viability.

The only known full-ship application of foul-release coatings to a submarine provides further evidence of the susceptibility of foul-release coatings to mechanical damage. The Australian Navy, in an attempt reduce self-generated noise while complying with the recent prohibitions on TBT-bearing antifouling coatings, tested a commercially available foul-release coatings and applied Intersleek to the HMAS FARNCOMB, the second of Australia's new COLLINS-Class submarines with flexible hulls similar to Navy submarines (DSTO, 1995). Damage to the foul-release coating and the resultant marine growth was considered excessive prior to sea-trials (i.e. within a few months after leaving drydock), and the use of foul-release coatings was discontinued (Holmdahl, 2000). It is not known if the coating damage observed on the HMAS FARNCOMB was the result of cleaning the vessel in port, or if the susceptibility of foul-release coatings to mechanical damage is increased when applied to flexible substrates. Before foul-release coatings could be applied to U.S. Navy submarines, performance validation testing would be required on an existing Navy nuclear submarine to ensure that significant damage would not occur to critical shipboard systems. Validation testing has not been done.

Based on the significant impact on the vessel's mission, the use of foul-release is not feasible for the flexible hulls vessel group and no further analysis is required.

3.3 Advanced Antifouling Coatings

The use of advanced antifouling coatings on flexible hulls is not approved by the current Navy manuals, policy, and specifications for underwater hull antifouling coatings. Panels coated with *E Paint SN-1* were fouled excessively in initial testing conducted by the Navy and do not meet the minimum performance requirements of military specification MIL-PRF-24647 (Lawrence, 2003). Therefore, this MPCD option is not feasible for the flexible hulls vessel group and no further analysis is required.

4.0 FEASIBILITY ANALYSES - ALUMINUM HULLS

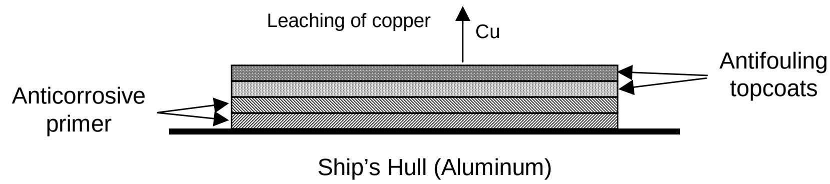
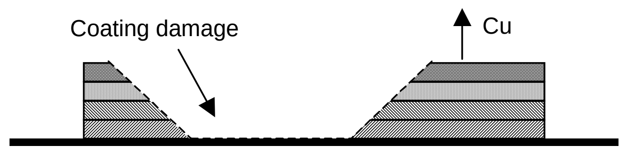
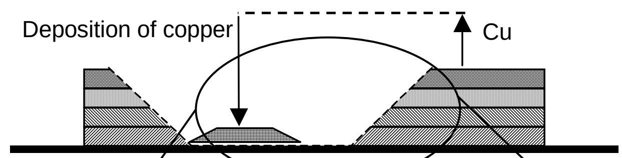
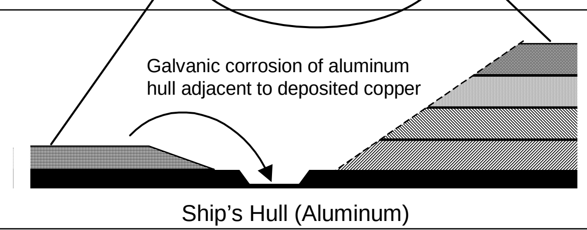
The feasibility of implementing the three MPCD options for the aluminum hulls vessel group is assessed in the following sections. The aluminum hulls vessel group, while not the smallest vessel group by number of vessels, has the smallest total wetted surface area of the vessels groups in this discharge. 400 vessels are included in this group, which accounts for 11% of the vessels and less than 0.5% of the wetted surface area in the hull coating leachate discharge.

For the aluminum hulls vessel group, the choice of coating used is determined locally based on the location and mission requirements of the vessel. Approximately 90% of USCG UTB 41, MLB 47, and ANB 55 class vessels are coated with advanced antifouling coatings and 10% are coated with foul-release coatings (Dust, 2003a). These vessel classes represent 75% of vessels in the aluminum hulls vessel group. As in previous sections, *E Paint SN-1* is the basis for the advanced antifouling coating analyses; and Intersleek 425 is the basis for the foul-release coating analyses.

4.1 Establish a Maximum Allowable Copper Release Rate for Antifouling Coatings

The use of copper-containing coatings on aluminum hulls is not approved by the current manuals, policy, and specifications for underwater hull antifouling coatings due to the possibility of deposition corrosion (Navy, 2001a; USCG, 2001). Deposition corrosion occurs when copper from the antifouling coating plates out onto an area of bare aluminum substrate, leading to galvanic corrosion of the hull as depicted in Table 4-1 (Jones, 1992; Lamtec, 2001). Therefore, this MPCD option is not feasible for the aluminum hulls vessel group and no further analysis is required.

Table 4-1—Steps Involved in Deposition Corrosion

Step	Description	Schematic
1	Application of typical copper-containing antifouling coating to an aluminum hull; copper leaches into the surrounding seawater	
2	Mechanical damage occurs to the coating system, exposing bare aluminum	
3	Copper is deposited (plated) as metallic copper on the bare aluminum	
4	Metallic copper causes galvanic corrosion of adjacent areas of bare aluminum	

4.2 Foul-Release Coatings

Current practice includes the use of both foul-release (10%) and advanced antifouling (90%) coatings on aluminum hulls. The feasibility of using only foul-release coatings for the aluminum hulls vessel group is presented in the following sections. Foul-release coatings, which contain no biocides, have a surface chemistry for which any fouling organisms that adhere to the hull may be dislodged by the flow of water across the hull or by hull cleaning. The basis for all analyses is International Intersleek 425, which has been approved for use on selected Armed Forces craft (e.g., vessels with aluminum hulls, vessels with drydock cycles less than five years, and vessels that have specialized acoustic performance requirements).

4.2.1 Practicability and Operational Impact Analysis

The practicability of requiring foul-release coatings on the representative vessel class is presented in the following sections.

4.2.1.1 Mission Capabilities

Hulls coated with foul-release coatings become more quickly fouled when sitting pierside or where the coating has been damaged (Navy and EPA, 2003b). When the foul-release coating is intact, the fouling that attaches pierside is removed by the flow of water across the hull during moderate and high-speed operations.

The limited durability of foul-release coatings would result in their limited use in specific geographic regions. As previously stated, transit through areas with sediment, debris, or ice may damage the coating and cause more frequent docking.

4.2.1.2 Drydocking Interval and Pierside Maintenance

The impact of this MPCD option on drydocking interval and pierside maintenance is discussed as a single factor. The frequency of hull cleaning is directly related to the drydocking interval. The maintenance cycle of the representative vessel is based on the condition of each individual vessel and varies considerably with location.

Although small boats and craft are typically removed from the water for maintenance using a travel or boat lift, the term "drydocking" is retained for section titles to maintain consistency with other vessel groups and section titles. The terms "launching" and "hauling" more accurately describe the procedures for removing small boats or craft from the water for maintenance and will be used in these sections.

Based on USCG experience, the MLB 47 class representative vessel is estimated to be hauled and cleaned approximately every six months, and hauled for re-preservation every 3 years when foul-release coatings are used (USCG, 2000). A typical maintenance cycle for the foul-release coating MPCD is presented in Table 4-2.

Table 4-2—Typical Maintenance Cycle for Foul-Release Coatings on a MLB 47 Class Vessel

Activity	**Timeline** (months)
Launch	0
Hauling and cleaning	6
	12
	18
	24
	30
Hauling and repainting	36

4.2.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

4.2.2.1 Initial Costs

Modifications to military specifications and manuals are required to mandate the use of foul-release coatings on vessels. Initial costs for the foul-release MPCD option are estimated for the updating of existing USCG manuals for coatings. An estimate of the specifications and contracts that require updating and the associated costs are presented in Table 4-3.

Table 4-3—Initial Cost of Implementing the Foul-Release Coatings MPCD for the Aluminum Hulls Vessel Group

Specification Modified	**Cost Estimate** ($K, in 1999 dollars)
USCG Coatings and Color Manual	12
Total:	**12**

The cost includes the labor to develop and draft changes to existing specifications and manuals. Performance data and criteria are assumed to exist to support the updating of the military specification. Additional costs are necessary if development and evaluation of coating performance standards is required.

4.2.2.2 Recurring Costs

Recurring costs include the cost of re-preservation, hull cleaning, and hauling the vessel for each of these operations.

The cost to haul the representative vessel is estimated to be $1,000 per operation based on the mid-range of values received from the USCG (Dust, 2003b).

Hull cleaning of the MLB 47 class is performed by USCG personnel with the vessel removed from the water. The cleaning costs are estimated by multiplying the reported hours per hull cleaning operation by the E-5 military pay grade as reported in the FY 1999 Annual Department of Defense (DoD) Composite Rate prepared by the Office of the Under Secretary of Defense Comptroller. The E-5 grade was selected based on the assumption that a sailor of E-5 grade performs the majority of the operation. The cost to clean the hauled vessel is estimated at $280 per cleaning, assuming two hours of labor by three USCG personnel (Dust, 2003d).

Re-preservation of the vessel entails old coating removal, surface preparation, paint procurement, application, quality assurance requirements, and solid waste disposal. The cost of re-preservation is estimated at $11,000 (USCG, 2000). Re-preservation costs are incurred once every three years. Re-preservation costs are presented in Table 4-4 based on data for the year 1999.

Table 4-4—Recurring Costs of the Foul-Release Coatings MPCD for a MLB 47 Class Vessel

Item	Number of Events	Cost ($K, 1999 dollars)
Hauling	24	
Cost per Drydocking		1
Cost Over 12-Year Period		24
Complete Re-preservation	4	
Cost per Operation		11
Cost Over 12-Year Interval		44
Hull Cleaning	20	
Cost per Cleaning		0.28
Cost per 12-Year Period		5.6
Total Recurring Costs – Over 12-Year Period per Vessel		**74**
Total Recurring Costs – Annual Basis per Vessel		**6.1**

4.2.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the foul-release coatings MPCD are presented in Table 4-5.
[[PLACEHOLDER – insert ACEIT results here]]

Table 4-5—Total Ownership Costs for the Foul-Release Coating MPCD for a MLB 47 Class Vessel

Cost Item	Cost ($K, in 1999 dollars)
Total Initial	12
Total Recurring	74
TOC - 12-year Period	81
Annualized	**6.7**

4.3 Advanced Antifouling Coatings

The feasibility of using advanced antifouling coatings for the aluminum hulls vessel group in the place of the current mixture of foul-release and advanced antifouling coatings is presented in the following sections. Advanced antifouling coatings are currently used on approximately 90% of the representative vessel class (Dust, 2003a). Advanced antifouling coatings reduce the discharge of metals through the use of non-metallic biocides.

The advanced antifouling coating, *E Paint SN-1*, is the basis for all analyses. *E Paint SN-1* has been approved for use by the USCG, but has not met the minimum performance requirements of military specification MIL-PRF-24647 and is not permitted for use on Navy vessels. *E Paint SN-1* has an active non-metallic biocide to control fouling, but a short service life of one to two years with supplemental hull cleanings (USCG 2000; Navy and EPA, 2003c).

4.3.1 Practicability and Operational Impact Analysis

The practicability of requiring advanced antifouling coatings on the representative vessel class is presented in the following sections.

4.3.1.1 Mission Capabilities

E Paint SN-1 has an active non-metallic biocide to control fouling and has an estimated service life of one to two years with supplemental hull cleanings (USCG, 2000; Navy and EPA, 2003c). The hulls of vessels that use advanced antifouling coatings become fouled after the first year of service as the active biocide is depleted, necessitating more frequent hull cleanings to reduce the impact on a vessel's speed and range. After the first year of service, it is assumed periodic hull cleanings are required.

4.3.1.2 Drydocking Interval and Pierside Maintenance

The maintenance cycle of the representative vessel is condition based and varies considerably with location. In sub-tropical areas such as Florida, vessels using advanced antifouling coatings may need to be repainted every 12 months and cleaned every four months. In colder climates, vessels may need to be repainted every two years and cleaned every six months after the first year of service (USCG, 2000).

For this analysis, hull cleanings are assumed to be required every six months after the first 12 months of service, as vessels are hauled and cleaned as required (Dust, 2003c). This schedule reflects the predicted depletion of the toxic biocide with time. A typical maintenance cycle for the advanced antifouling coating MPCD is presented in Table 4-6.

Table 4-6—Typical Maintenance Cycle for Advanced Antifouling Coatings on a MLB 47 Class Vessel

Activity	**Timeline** (months)
Launch	0
Hauling and cleaning	12
	18
	21
Hauling and repainting	24

4.3.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

4.3.2.1 Initial Costs

Modifications to military specifications and manuals are required to mandate the use of advanced antifouling coatings on vessels. Initial costs for the advanced antifouling coatings MPCD option are estimated for updating existing Navy and USCG military specifications and manuals (Navy

2003a). An estimate of the specifications and contracts that require updating and the associated costs, are presented in Table 4-7.

Table 4-7—Initial Cost of Implementing the Advanced Antifouling Coatings MPCD for the Aluminum Hulls Vessel Group

Specification Modified	Cost Estimate ($K, in 1999 dollars)
Navy NSTM Chapter 631	12
Navy MIL-PRF-24647	25
NAVSEA Standard Item 009-32	6
USCG Coatings and Color Manual	12
Total:	**55**

The cost includes the labor to develop and draft changes to existing specifications and manuals. Performance data and criteria are assumed to exist to support the updating of the military specification. Additional costs are necessary if development and evaluation of coating performance standards is required.

4.3.2.2 Recurring Costs

Recurring costs include the cost of re-preservation, overcoating (as described below), hull cleaning, and the cost to haul the vessel for each of these operations.

The cost to haul the representative vessel is assumed to be $1,000 per operation based on the mid-range of values received from the USCG (Dust, 2003b)

Hull cleaning of the MLB 47 class is performed by USCG personnel with the vessel removed from the water. The cleaning costs are estimated by multiplying the reported hours per hull cleaning operation by the E-5 military pay grade as reported in the FY 1999 Annual Department of Defense (DoD) Composite Rate prepared by the Office of the Under Secretary of Defense Comptroller. The E-5 grade was selected based on the assumption that a sailor of E-5 grade performs the majority of the operation. The cost to clean the vessel is estimated at $540 per cleaning, assuming four hours of labor by three USCG personnel (Dust, 2003d).

For the advanced antifouling coatings MPCD in the aluminum hulls vessel group, repainting of a vessel is accomplished by overcoating or complete re-preservation. The overcoating process includes cleaning, roughening the existing surface, and then applying a new topcoat. The estimated cost for overcoating is $3,000. The ease of hauling aluminum vessels and applying advanced antifouling coatings make overcoating a viable practice. Complete re-preservation of the vessel entails abrasive grit blasting the hull to bare metal, preparing the surface, and application of coatings. Complete re-preservation cost is estimated at $8,000, which includes labor, paint procurement, solid waste disposal, and other material costs. The USCG estimates overcoating can be accomplished twice before a complete re-preservation is required (USCG, 2000). Therefore, overcoating occurs at the two- and four-year service life mark and complete re-preservation occurs at six years of service.

Recurring costs over a 12-year interval for this MPCD option are presented in Table 4-8.

Table 4-8—Recurring Costs of the Advanced Antifouling Coatings MPCD for a MLB 47 Class Vessel

Item	**Number of Events**	**Cost** ($K, in 1999 dollars**)**
Hauling	24	
Cost per Drydocking		1
Cost Over 12-Year Period		24
Complete Re-preservation	2	
Cost per Operation		8
Cost Over 12-Year Interval		16
Overcoating	4	
Cost per Operation		3
Cost Over 12-Year Interval		12
Hull Cleaning	18	
Cost per Cleaning		0.54
Cost per 12-Year Period		9.7
Total Recurring Costs – Over 12-Year Period per Vessel		**62**
Total Recurring Costs – Annual Basis per Vessel		**5.1**

4.3.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the Advanced Antifouling Coatings MPCD are presented in Table 4-9.

Table 4-9—Total Ownership Costs for the Advanced Antifouling MPCD for a MLB 47 Class Vessel

Cost Item	**Cost** ($K, in 1999 dollars)
Total Initial	55
Total Recurring	62
TOC - 12-year Period	113
Annualized	**9.4**

4.4 Current Practice

The current choice of hull coatings for the aluminum hulls vessel group is determined locally based on the location and use of the vessel. Approximately 90% of vessels are coated with advanced antifouling coatings and 10% of vessels are coated with foul-release coatings (Dust, 2003a). As in previous sections, *E Paint SN-1* is the basis for the advanced antifouling coating analyses; Intersleek 425 is the basis for the foul-release coating analyses.

4.4.1 Practicability and Operational Impact Analysis

The practicability and operational impact of the MPCD option are addressed in the following subsections. Feasibility factors are addressed only to the extent necessary to support comparison to other MPCD options in subsequent sections.

4.4.1.1 Mission Capabilities

The current practice is to decide on the use of foul-release or advanced antifouling coatings locally taking into account local conditions and vessel mission. For small boats and craft, the flexibility of this current practice permits each locality to select coatings that best satisfy mission requirements and local operational restrictions (i.e., the availability of boat lifts and capability to repair/apply foul-release and/or advanced antifouling coatings).

USCG experience has shown a preference for using advanced antifouling coatings when mission requirements are considered, because advanced antifouling coatings are more durable and do not foul as easily when sitting pierside. If travel or boat lifts are available and cost effective and vessel operations will not damage the underwater hull coatings, foul-release coatings remain a viable option. As discussed previously, the Navy does not use *E Paint SN-1*.

4.4.1.2 Drydock and Pierside Maintenance

A comparison of the typical maintenance cycles for advanced antifouling and foul-release coatings is presented in Table 4-10.

Table 4-10—Comparison of the Typical Maintenance Cycle for Advanced Antifouling and Foul-Release Coatings on a MLB 47 Class Vessel

Activity	Timeline (months)	
	Advanced Antifouling Coatings	Foul Release Coatings
Launch	0	0
Hauling and cleaning	12	6
	18	12
	21	18
		24
		30
Hauling and repainting	24	36

Over a 12-year period, the number of estimated pierside maintenance activities for these coatings are similar as illustrated in Table 4-11.

Table 4-11—Pierside Maintenance Activities Over a 12-Year Interval for Advanced Antifouling and Foul-Release Coatings on a MLB 47 Class Vessel

Activity	Number of Estimated Activities Over a 12-year Interval	
	Advanced Antifouling Coatings	Foul Release Coatings
Hauling and Complete Re-preservation	2	4
Hauling and Overcoating	4	N/A
Hulling and Cleaning	18	20

4.4.2 Cost Analysis

The initial, recurring, and total ownership costs associated with this MPCD option are presented in the following sections.

4.4.2.1 Initial Costs

Modifications to military specifications and manuals are not required and initial costs are not incurred, because this is the current practice.

4.4.2.2 Recurring Costs

The current practice is a mixture of foul-release and advance antifouling coatings. Individual recurring costs for foul-release advanced antifouling coatings are presented in Sections 4.2.2.2 and 4.3.2.2, respectively.

Approximately 90% of vessels are estimated to use advanced antifouling coatings and 10% are estimated to use foul-release coatings. Total recurring costs over a 12-year basis were estimated by adjusting the values presented in previous sections with the percentage used. Recurring costs, over a 12-year maintenance interval, are presented in Table 4-12.

Table 4-12—Recurring Costs of the Current Practice for a MLB 47 Class Vessel

Item	**Recurring Cost** ($K, in 1999 dollars)
Total Recurring Costs – Over 12-Year Period per Vessel	59
Total Recurring costs – Annual Basis per Vessel	4.9

4.4.2.3 Total Ownership Costs

A summation over a 12-year period of the initial, recurring, and Total Ownership Costs and the annualized costs for the Advanced Antifouling Coatings MPCD are presented in Table 4-13.

Table 4-13—Total Ownership Costs for the Current Practice for a MLB 47 Class Vessel

Cost Item	**Cost** ($K, in 1999 dollars)
Total Initial	0
Total Recurring	59
TOC - 12-year Period	55
Annualized	4.6

5.0 SUMMARY

A summary of the feasibility impacts by vessel group and MPCD option is presented in Table 5-1. The maximum copper release rate MPCD option has the least impact for the steel, composite, and non-aluminum rigid hulls and flexible hulls vessel groups. For the aluminum hulls vessel group, the foul-release coatings MPCD option would have a significant impact on mission capabilities and pierside maintenance. The foul-release coatings and advanced antifouling coatings MPCD options were deemed not feasible for flexible hulls vessel group.

Table 5-1—Feasibility Impact Summary

	Analysis Factors				
	Mission Capabilities	Drydock and Pierside Maintenance	Initial Costs ($K, in 1999 dollars)	Recurring Costs ($K, in 1999 dollars)	Annualized TOC ($K, in 1999 dollars)
Steel, Composite, and Other Non-Aluminum Rigid Hulls –Vessel Class for Analysis: USS NIMITZ[1]					
Baseline/Current Practice	None	None	0	1,500	130
Max Copper Standard	None	None	42	1,500	130
Foul-Release Coatings	Reduces speed, range, and mission availability	4-fold increase in drydocking frequency; 6-fold increase in pierside maintenance	48	7,000	580
Advanced Antifouling Coatings	Reduces speed, range, and mission availability	5-fold increase in drydocking frequency; 3-fold increase in pierside maintenance	73	9,300	770
Flexible (Non-Aluminum) Hulls - Representative Vessel Class: USS LOS ANGELES					
Baseline/Current Practice	None	None	0	310,000	26,000
Max Copper Standard	None	None	36	310,000	26,000
Foul-Release Coatings	Possible impacts to critical shipboard systems. MPCD option is not feasible.				
Advanced Antifouling coatings	Coating not approved for Navy vessels. Test panels fouled excessively in initial Navy testing showing advanced coatings do not meet minimum performance requirements. MPCD option is not feasible.				
Aluminum Hulls - Representative Vessel Class: MLB 47					
Baseline/Current Practice	None	None	0	21,000	1,800
Max Copper Standard	The use of copper-containing antifouling paints would lead to deposition corrosion. This MPCD option is not feasible.				
Foul-Release Coatings	Reduces speed, range, and mission availability	Increased pierside maintenance	12	25,000	2,100
Advanced Antifouling Coatings	None	None	55	21,000	1,800

[1] A representative vessel class was not selected for this vessel group. Costs are related to vessel size (see Section 2.0 for details.)

6.0 REFERENCES

ACEIT. 2001. ACEIT Customers, Automating the Estimating Environment, http://www.aceit.com/main/aceitcustomers.asp. Accessed 11 June 2001.

ASM International. 1987. ASM Handbook Volume 13 CORROSION. ASM International.

ASTM. 2000. ASTM D 6442, Standard Test Method for Copper Release Rates of Antifouling Coating Systems in Seawater, American Society for Testing and Materials (ASTM). February 2000.

Coatingsworld. 2002. Webpage www.coatingsworld.com/Jan022.htm. Accessed 22 May 2002.

DSTO, 1995. Media Release DSTO 22/95, Defense Science and Technology Organisation, Melbourne, Australia, 15 December 1995.

Dust, M. 2003a. "UNDS Hull Paint Systems for Aluminum Vessels." Email response to A. Yue. 08 January 2003.

Dust, M. 2003b. "Cost of Drydock for 47 MLB." Email response to A. Yue, 05 February 2003.

Dust, M. 2003c. "Drydock schedule for 47 MLB." Email response to A. Yue, 06 February 2003.

Dust, M. 2003d. Conversation with Mr. Mark Dust, U.S. Coast Guard and Michael Shimko, AMSEC LLC, Washington, D.C. 10 April 2003.

EPA and DOD. 2000. Feasibility Impact Analysis Guidance Document for Phase II of the Uniform National Discharge Standards for Vessels of the Armed Forces. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and U.S. Navy, Naval Sea Systems Command, Washington, DC. Date

Hempel. 2001. Hempasil SP-EED 77500 [product information]. Hempel Marine Paints A/S. February 2001.

Hess, 2001. Hess, R., Rushworth, R., Hynes, M., and Petes, J., Disposal Options for Ships, RAND Organization webpage. http//www.rand.org/publications.mr/mr1377/. Accessed 13 May 2003.

Holmdahl, 2000. "COLLINS – A Contractor's Perspective", Olle Holmdahl, UDT Pacific 2000, Undersea Defense Technology Conference and Exhibition, Darling Point, Sydney, Australia, 7-9 February 2000.

Ingle, M. 2002. Antifouling Coatings Industry Status and Program Summary, U.S. Navy Briefing to the EPA. March 2002.

International Marine Coatings. 2001. Intersleek 700 [product information]. 2001. International Marine Coatings Home Page. http://www.intersleek700.com/. Accessed 25 April 2001.

International Marine Coatings. 2003. Conversation with Mr. William Allanach, International Marine Coatings Government Marketing Representative, and Michael Shimko, AMSEC LLC, Washington, D.C. 22 April 2003

Jones, D.A. 1992. Principles and Prevention of Corrosion. Macmillan Publishing Company, New York, New York.

Lamtec. 2001. Lamtec Corporation, Chemical Resistance of Polypropylene. http://www.lamtec.com/corrosion.htm. Accessed 11 February 2003.

Lawrence, S. 2003. SN-1 NO FOUL. Email response to J. Tock. 21 February 2003.

Marlin Paint. 2001. SIL-MAR [product information]. 2001. Marlin Paint Home Page. http://www.marlinpaint.com/frame.html. Accessed 25 April 2001.

McCue, T. 2002b. Meeting with Mr. Thomas McCue of NAVSEA, 00C and Mr. Kurt Kacprzynski, Booz Allen Hamilton, Washington, D.C. 16 July 2002.

McCue, T. 2003a. Feasibility of Changing Frequency of Full and Interim Cleaning, memorandum ser 5001 to SEA 05M4 (G, Smith), 3 January 2003.

McCue, T. 2003b. Conversation with Mr. Thomas McCue of NAVSEA, 00C, and Mr. Michael Shimko, AMSEC LLC, Washington, D.C. 13 May 2003.

Mine. 2002. Mine Countermeasures Platforms and Systems Platforms Web Page. 9 April 2002. Chief of Naval Operations, Expeditionary Warfare. http://www.exwar.org/mwp/appendix_d2.htm. Accessed 18 April 2002

Navy. 1992a. Maintenance Requirement Card A2B8BTN, "Steam out sea chest." Operations, Navy 4790/85. 1992.

Navy. 1994. Military Specification MIL-P-15931F, Amendment 1, Paint, Antifouling, Vinyl, Formula 121A/129A. Naval Sea Systems Command, Washington, DC. 16 September 1994

Navy. 1999. Waterborne Underwater Hull Cleaning of Navy Ships. Naval Ships' Technical Manual Chapter 81. Naval Sea Systems Command. S9086-CQ-STM-010/CH-81. 1 April 1999.

Navy. 2001a. Military Specification MIL-PRF-24647C, Performance Specification: Paint System, Anticorrosive and Antifouling, Ship Hull. Naval Sea Systems Command, Washington, DC. 24 September 2001.

Navy. 2001b. Preservation of Ships in Service. Naval Ships' Technical Manual (NSTM) Chapter 631, Volume 1, Revision 2. Naval Sea Systems Command. S9086-VD-STM-010/Ch-631V1R2. 1 December 2001.

Navy. 2003. Cost Estimates for Updating Specifications and Standards. 4 August 2003.

Navy and EPA. 2003a. MPCD Screen – Establish a Maximum Allowable Copper Release Rate for Current and Future Antifouling Coatings. U.S. Department of the Navy and U.S. Environmental Protection Agency. 10 January 2003.

Navy and EPA. 2003b. MPCD Screen – Foul-Release Coatings. U.S. Department of the Navy and U.S. Environmental Protection Agency. 10 January 2003.

Navy and EPA. 2003c. MPCD Screen – Advanced Antifouling Coatings. U.S. Department of the Navy and U.S. Environmental Protection Agency. 8 August 2003.

Navy and EPA. 2003d. *Vessel Grouping and Representative Vessel Class Selection for Hull Coating Leachate Discharge*. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and U.S. Department of the Navy, Naval Sea Systems Command, Washington, DC. 21 August 2003.

Navy and EPA. 2003e. Environmental Effects and Analysis Report for Underwater Ship Husbandry Discharge. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and U.S. Department of the Navy, Naval Sea Systems Command, Washington, DC. 4 August 2003.

OMB. 1992. Circular No. A-94 Revised (Transmittal Memo No. 64). Memorandum for Heads of Executive Departments and Establishments. Office of Management and Budget. Washington, DC. 29 October 1992.

Shimko, M. 1998. Shimko, Michael, P.E., "Innovative Hull Preservation Systems Feasibility Study." M. Rosenblatt & Son, an AMSEC LLC Group. 21 May 1998.

Shimko and Tock. 2003. MIL-P-15931 (vinyl) Antifouling Coating Information. Michael Shimko and John Tock, AMSEC LLC, Washington, D.C. 3 April 2003.

USCG. 1999a. Maintenance Procedure Card (MPC) A-W-3380, "Inspect HVAC Raw Water Strainer." 26 April 1999.

USCG. 1999b. Maintenance Procedure Card (MPC) M-M-3389, "Clean MDE Raw Water Strainers." 26 April 1999.

USCG. 2000. COMDT COGARD MSG R252345Z AUG 00, Naval Engineering Advisory 6/00: Authorization of No Foul SN-1 for Aluminum Hull Underwater Body. 25 August 2000.

USCG. 2001. Coatings and Color Manual. U.S. Coast Guard. COMDINST M10360.3B. 12 June 2001.

APPENDIX A - COMPARISON OF COST DATA

Initial Coats for Implementing MPCD (Specification Changes)

Item	**Maximum Copper Release Rate**	**Foul-Release Coatings**	**Advanced Antifouling Coatings**
	Cost ($K)	Cost ($K)	Cost ($K)
CVN 68			
NSTM (Navy)	12	12	12
MIL-PRF-24647	12		25
NAVSEA Standard Item 009-32	6	6	6
USCG Coatings and Color Manual	12	12	12
Army Procurement Contract		6	6
MSC Procurement Contract		6	6
Air Force Procurement Contract		6	6
Total	**42**	**48**	**73**
SSN 688			
Submarine Maintenance Manual	12		
NSTM (Navy)	12		
MIL-PRF-24647	12		
Total	**36**	n/a	n/a
MLB 47			
NSTM (Navy)			12
MIL-PRF-24647			25
NAVSEA Standard Item 009-32			6
USCG Coatings and Color Manual		12	12
Army Procurement Contract			
MSC Procurement Contract			
Air Force Procurement Contract			
Total	n/a	**12**	**55**

Recurring Costs for Implementing MPCD - Drydocking Costs

Item	**Copper Ablative Coatings**		**Foul-Release Coatings**		**Advanced antifouling coatings**	
	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)
CVN 68	1		4		6	
Costs per Drydocking)		2,200		2,200		2,200
Costs over 12-year period		2,200		8,800		13,200
SSN 688	4		n/a		n/a	
Costs per Drydocking		950		n/a		n/a
Costs over 12-year period		3,800		n/a		n/a
MLB 47	n/a		24		24	
Costs per Drydocking		n/a		1		1
Costs over 12-year period		n/a		24		24

Recurring Costs for Implementing MPCD - Re-preservation Costs

Item	**Copper Ablative Coatings**		**Foul-Release Coatings**		**Advanced antifouling coatings**	
	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)
CVN 68	1		4		6	
Costs per Operation		1,400		2,100		1,600
Costs over 12-year period		1,400		8,400		9,600
SSN 688	4		n/a		n/a	
Costs per Operation		310		n/a		n/a
Costs over 12-year period		1,200		n/a		n/a
MLB 47	n/a		4		2	
Costs per Operation		n/a		11		8
Costs over 12-year period		n/a		44		16
					4*	
Costs per Operation						3*
Costs over 12-year period						12*

* For overcoating vice complete re-preservation as described in Section 4.3.2.2

Recurring Costs for Implementing MPCD - Hull Cleaning Costs

Item	Maximum Copper Release Rate		Foul-Release Coatings		Advanced Antifouling Coatings	
	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)	Number of Operations	Cost ($K)
CVN 68	3		20		12	
Costs per Cleaning		68		34		68
Costs over 12-year period		200		680		820
SSN 688	15		n/a		n/a	
Costs per Cleaning		17		n/a		n/a
Costs over 12-year period		260		n/a		n/a
MLB 47	n/a		20		18	
Costs per Cleaning		n/a		0.28		0.54
Costs over 12-year period		n/a		5.6		9.7

Total Ownership Costs of Implementing MPCD

Item	Maximum Copper Release Rate	Foul-Release Coatings	Advanced Antifouling Coatings
	Cost ($K)	Cost ($K)	Cost ($K)
CVN 68			
Total Initial	42	48	73
Total Recurring	3,800	18,000	23,620
TOC – 12-year Period	3,571	16,763	22,007
Annualized	298	1,397	1,834
SSN 688			
Total Initial	36	n/a	n/a
Total Recurring	5,260	n/a	n/a
TOC – 12-year Period	4,921	n/a	n/a
Annualized	410	N/a	n/a
MLB 48			
Total Initial	n/a	12	55
Total Recurring	n/a	74	62
TOC – 12-year Period	n/a	81	113
Annualized	n/a	6.7	9.4

APPENDIX B - MAINTENANCE CYCLES

CVN 68 (through 12 years (144 months))

Action	Occurrence (months)		
	Copper Ablative Coatings	**Foul-Release Coatings**	**Advanced antifouling coatings**
Undock	0	0	0
Hull cleaning	46	6	
Hull cleaning	86	12	12
Hull cleaning	116	18	18
Hull cleaning		24	
Hull cleaning		30	
Drydock and repaint	**144**	**36**	**24**
Hull cleaning		42	36
Hull cleaning		48	42
Hull cleaning		54	
Hull cleaning		60	
		66	
Drydock and repaint		**72**	**48**
Hull cleaning		78	60
Hull cleaning		84	66
Hull cleaning		90	
Hull cleaning		96	
		102	
Drydock and repaint		**108**	**72**
Hull cleaning		114	84
Hull cleaning		120	90
Hull cleaning		126	
Hull cleaning		132	
		138	
Drydock and repaint		**144**	**96**
Hull cleaning			108
Hull cleaning			114
Drydock and repaint			**120**
Hull cleaning			132
Hull cleaning			138
Drydock and repaint			**144**

SSN 688 (through 10 years (120 months))

Action	**Occurrence (months)**		
	Copper Ablative Coatings	**Foul-Release Coatings**	**Advanced antifouling coatings**
Undock	0	**N/A**	**N/A**
Hull cleaning	8		
Hull cleaning	16		
Hull cleaning	24		
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Drydock and repaint	**30**		
Hull cleaning	38		
Hull cleaning	46		
Hull cleaning	54		
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Drydock and repaint	**60**		
Hull cleaning	68		
Hull cleaning	76		
Hull cleaning	84		
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Drydock and repaint	**90**		
Hull cleaning	98		
Hull cleaning	106		
Hull cleaning	114		
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Hull cleaning			
Drydock and repaint	**120**		

MLB 47 (through 6 years (72 months))

Action	**Occurrence (months)**		
	Copper Ablative Coatings	**Foul-Release Coatings**	**Advanced antifouling coatings**
Undock	**N/A**	**0**	**0**
Hull cleaning		6	12
Hull cleaning		12	18
Hull cleaning		18	21
Hull cleaning		24	
Hull cleaning		30	
Drydock and repaint		**36**	**24**
Hull cleaning		42	36
Hull cleaning		48	42
Hull cleaning		54	45
Hull cleaning		60	
Hull cleaning		66	
Drydock and repaint		**72**	**48**
Hull cleaning			60
Hull cleaning			66
Hull cleaning			69
Drydock and repaint			**72**